NEW QCD RESULTS FROM NUTEV

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The NuTeV Collaboration

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Preliminary results from next-to-leading order strange sea fits to the NuTeV's deep inelastic scattering charged-current dimuon cross section data are presented. Preliminary neutrino and antineutrino inclusive charged-current differential cross sections and preliminary structure function $F_2(x, Q^2)$ are presented.

Introduction

Neutrino-nucleon deep inelastic scattering (DIS) probes the structure of the nucleon and QCD. The NuTeV experiment is a high-energy fixed target νN scattering experiment [1], which combines two new features: separate high-purity neutrino and antineutrino beams, used to tag the primary lepton in charged-current interactions, and a continuous precision calibration beam which improves the experiment's knowledge of the absolute energy scale for hadrons and muons produced in neutrino interactions [2]. 8.6×10^5 ν and 2.3×10^5 $\overline{\nu}$ charged-current (CC) interactions passing analysis cuts were collected during NuTeV's data taking run.

NLO Charm Production

Charm production occurs in CC interactions when $\nu(\overline{\nu})$ scatters off $s(\overline{s})$ or $d(\overline{d})$ quarks in the nucleon. Charm production from d quarks is Cabbibo suppressed, which allows sensitivity to the strange parton distribution function (PDF). The charmed hadron produced in this interaction decays semileptonically to a muon about 10% of the time providing a distinct signature of two final state muons of opposite sign. The high-purity beam tags the sign of the muon from the primary vertex and allows an independent measurement of strange and antistrange seas.

The presence of a large gluon sea in the nucleon requires the strange sea fit to be performed at NLO in QCD. A new NLO calculation [3] implemented into a FORTRAN routine DISCO [4], calculates the differential cross section for charm production as differential in x, y, fragmentation momentum ratio z, and charm rapidity η_c.
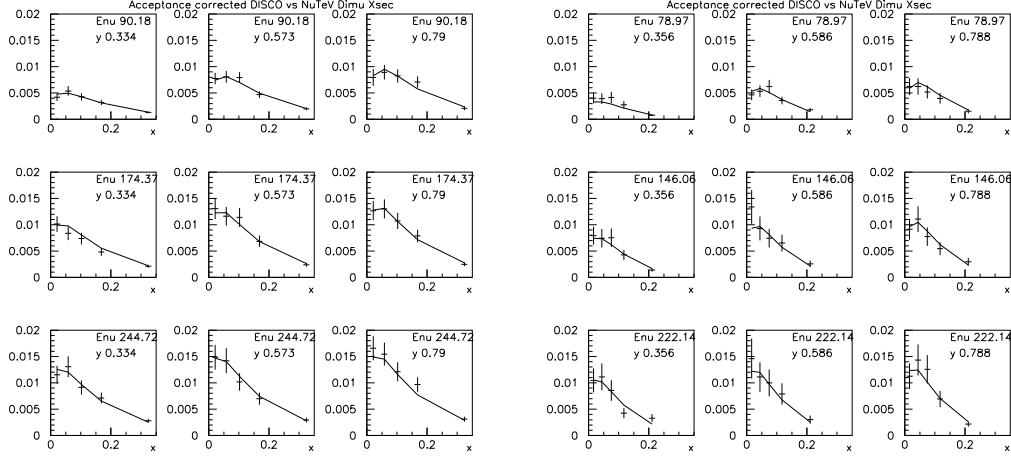
Figure 1: NuTeV's forward dimuon cross section (crosses) with the NLO fit curve for ν (left) and $\overline{\nu}$ (right).

parameter	fit value	stat.	syst.
m_c	1.46	± 0.24	± 0.07
κ	0.516	± 0.033	± 0.031
$\overline{\kappa}$	0.511	± 0.038	± 0.040
α	0.73	± 0.47	± 0.52
$\overline{\alpha}$	0.92	± 0.43	± 0.06
ϵ	0.20	± 0.13	± 0.04
χ^2/dof	36.2/38		

Table 1: Preliminary 6-parameter fit to the NuTeV's dimuon cross section table.

NuTeV recently published a measurement of the differential cross section for forward dimuon production[5], with the muon from charm decay, required to have energy $E_{\mu 2} > 5$ GeV. A NLO fit to the forward dimuon cross section is performed using,

$$\frac{d^2\sigma_{2\mu}}{dxdy} = \frac{d^2\sigma_{charm}}{dxdy} \times EMC \times B_c \times A \qquad (1)$$

where $\frac{d^2\sigma_{2\mu}}{dxdy}$ is the measured NuTeV dimuon cross section, $\frac{d^2\sigma_{charm}}{dxdy}$ is the NLO cross section model integrated over z and η_c, EMC is an x dependent correction for the EMC effect and nuclear shadowing, B_c is the semileptonic charm branching ratio ($B_c = 0.093$[6] is used in the fit), and A is an acceptance correction accounting for the minimum energy cut on $E_{\mu 2}$. The acceptance correction is a function of the fragmentation parameter ϵ and the charm mass m_c, in addition to x, y, and E_ν. Both cross sections are functions of neutrino energy E_ν.

Preliminary Strange Sea Fit Results

A preliminary fit to the NuTeV dimuon cross section table has been performed using the NLO cross section model described in the previous section. Collins-Spiller fragmentation parameter ϵ, charm mass m_c, κ, α, $\overline{\kappa}$, and $\overline{\alpha}$ are the 6 fit parameters. The $s(\overline{s})$ sea is parameterized using,

$$s(\overline{s}) = \kappa(\overline{\kappa})\frac{\overline{u}(x) + \overline{d}(x)}{2}(1 - x)^{\alpha(\overline{\alpha})} \qquad (2)$$
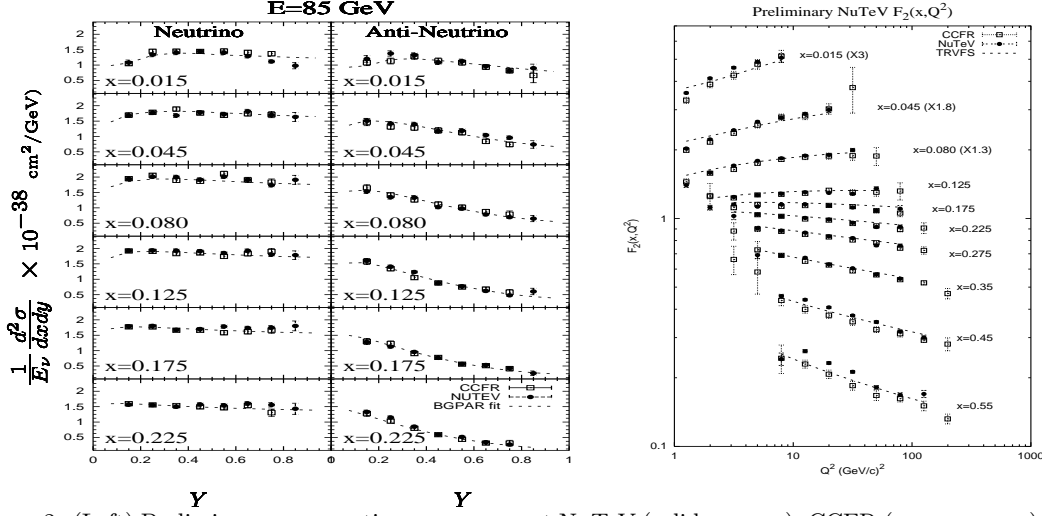
Figure 2: (Left) Preliminary cross section measurement NuTeV (solid squares), CCFR (open squares), curve shows QCD inspired fit to data. (Right) Preliminary F_2 measurement NuTeV (solid squares), CCFR (open squares), curve shows NLO QCD Model[12]. Statistical errors only.

in terms of the light-quark sea distributions. The GRV94HO[8] PDF's were used in the fit.

Fig. 1 shows the preliminary fit result and the dimuon cross section points for both neutrino and antineutrino mode. Fit parameters are given in Table 1. The NLO fit describes the data well. This result is the first NLO extraction with full differential dependence on η_c and z. This NLO model will be used to re-extract the dimuon cross section as a check.

ν-Fe CC Differential Cross Section and ν-Fe Structure Functions

The differential cross section is determined from

$$\frac{d^2\sigma^{\nu(\overline{\nu})}}{dxdy} = \frac{1}{\Phi(E)}\frac{d^2N^{\nu(\overline{\nu})}(E)}{dxdy}. \tag{3}$$

where $\Phi(E)$ is the $\nu(\overline{\nu})$ flux in energy bins. The cross section event sample is required to pass fiducial volume cuts, μ track reconstruction quality cuts, and minimum energy thresholds for muon energy ($E_\mu > 15$ GeV), hadronic energy ($E_{HAD} > 10$ GeV), and neutrino energy ($E_\nu > 30$ GeV). Selected events are binned in x, y, and E_ν bins, and corrected for acceptance and smearing using a detector simulation. $Q^2 > 1$ GeV^2/c^2 is required to minimize the non-perturbative contribution to the cross section. NuTeV data ranges from 10^{-3} to 0.95 in x, 0.05 to 0.95 in y, and from 30 GeV to 300 GeV in E_ν.

The flux is determined from data with $E_{HAD} < 20$ GeV using the "fixed ν_0" relative flux extraction method[1]. The integrated number of events in this sample as $y = \frac{E_{HAD}}{E_\nu} \to 0$ is proportional to the flux. Corrections, determined from the data sample, up to order y^2 are applied to determine the relative flux to about the 1% level. Flux is normalized using the world average ν-Fe cross section[7] $\frac{\sigma^\nu}{E_\nu} = 0.677 \times 10^{-38} cm^2/GeV$.

The detector simulation, which takes into account acceptance and resolution effects, uses an empirically determined set of PDFs extracted by fitting the differential cross section[9]. The procedure is then iterated until convergence is achieved (within 3 iterations). Detector response functions are parameterized from the NuTeV calibration beam data samples[2]. As a typical example, the differential cross section at $E = 85$ GeV is shown on Fig. 2(left). NuTeV is found to be in good agreement with CCFR[10].

Preliminary F_2 Structure Function Fit Result

The sum of the neutrino and antineutrino differential cross sections can be written in terms of ϵ, the polarization of W boson :

$$F(\epsilon) = \frac{\pi(1-\epsilon)}{y^2 G_F^2 M_p E_\nu} \left(\frac{d^2\sigma^\nu}{dxdy} + \frac{d^2\sigma^{\overline{\nu}}}{dxdy} \right) = 2xF_1 \left[1 + \epsilon R(x, Q^2) \right] + \frac{y(1-\frac{y}{2})}{1 + (1-y)^2 + M_p xy/E} \Delta xF_3.$$

$$(4)$$

where $\epsilon = \frac{2(1-y) - M_p xy/E}{1 + (1-y)^2 + M_p xy/E}$. $F_2(x, Q^2)$ is extracted from fits to the y distribution using R_{WORLD}[11] as input for $R(x, Q^2)$, and a NLO model[12] for ΔxF_3. Preliminary F_2 fit result is shown on Fig. 2 (right). Results are in good agreement with previous $\nu - Fe$ measurements for $x < 0.45$ and good agreement with QCD.

Conclusions and Prospects

NuTeV has new preliminary results on NLO charm production from fits to the NuTeV dimuon cross section. NLO charm mass parameter and $s(\overline{s})$ seas have been extracted from the fits. New preliminary measurements of the ν-Fe and $\overline{\nu}$-Fe CC differential cross sections and the structure function F_2 have been presented. Both are in good agreement with the results from previous ν-Fe experiments and QCD.

References

1. J. M. Conrad, M. H. Shaevitz, and T. Bolton, *Rev. Mod. Phys.* **70**, 4 (1998).
2. D. A. Harris *et al.*, *Nucl. Instrum. Methods* A **447**, 377-415 (2000).
3. M. Gluck, S. Kretzer, E. Reya, *Phys. Rev. Lett.* **88**, 1996 (171-176), S. Kretzer, I. Schienbein, *Phys. Rev.* D **58**, 094035 (1998).
4. S. Kretzer, D. Mason, F. Olness, *Phys. Rev.* D **65**, 074010 (2002).
5. M. Goncharov *et al.*, *Phys. Rev.* D **62**, 112006 (2001).
6. Bolton, T. 1997, "Determining the CKM parameters V_{CD} from νN Charm Production" KSU-HEP-97-04, e-print hep-ex/9708014
7. W. Seligman, Ph. D. Thesis (Columbia University), Nevis Reports 292, (1997).
8. M. Gluck, E. Reya, A. Vogt, *Z. Phys.* C **67**, 433-448 (1995).
9. A. J. Buras and K. L. F. Gaemers, *Nucl. Phys.* B **132**, 2109 (1978).
10. U. K. Yang *et al.*, *Phys. Rev. Lett.* **86**, 2001 (2742-2745).
11. L. W. Whitlow *et al.*,*Phys. Lett.* B **250**, 193 (1990).
12. R. S. Thorne and R. G. Roberts, *Phys. Lett.* B **421**, 303 (1998). A. D. Martin, R. G. Roberts, W. J. Stirling, and R. S. Thorne, *Eur.Phys.J.C* **18**, 117-126 (2000).